

**PREDATION ON DOUGLAS-FIR TUSSOCK MOTH
(LEPIDOPTERA: LYMANTRIIDAE) AND
WHITE FIR SAWFLY (HYMENOPTERA: DIPRIONIDAE)
LARVAE BY CAPTIVE SPIDERS FROM
WHITE FIR IN CALIFORNIA**

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Abstract.—Eighteen spider species commonly collected on white fir (*Abies concolor* Gordon & Glendinning) in California were tested in a laboratory study to determine if they would feed on Douglas-fir tussock moth (*Orgyia pseudotsugata* (McDunnough)) and white fir sawfly larvae (*Neodiprion abietis* (Harris) complex). All spider species fed on first, second, or third instar tussock moth larvae. Seven species fed on the fourth and fifth instar sawfly larvae that were available for the study. Their capacity to feed on these prey indicates that spiders may be important predators of white fir defoliators.

Key Words.—Insecta, *Orgyia pseudotsugata*, *Neodiprion abietis*, Araneae, *Abies concolor*, predation

Spiders are abundant in forests and may be important in regulating insects of concern to forest managers. There are numerous records of spider predation on Douglas-fir tussock moth (DFTM), sawflies, and other forest insects (Dahlsten 1961; Coppel & Smythe 1963; Whitcomb & Tadic 1963; Jennings & Pase 1975, 1986; Fox & Griffith 1976; Wickman 1977; Fichter & Stephen 1984; Jennings & Crawford 1985; Sheehan & Dahlsten 1985; Mason & Paul 1988). Most of the literature is observational rather than experimental. Reichert & Lockley (1984) reviewed evidence on the importance of spiders as biological control agents, emphasizing that their effectiveness is greatest in systems with minimum disruption. Assessments of the role of spiders in forest defoliator population dynamics vary (Jennings & Crawford 1985, Morris 1972). Weseloh (1989) reviewed work on spider predation on Lymantriidae and concluded that effects, when quantified, were small. However, Mason & Torgersen (1983, 1987), Mason & Overton (1983), and Mason et al. (1983) suggest that predation by spiders may be important in larval DFTM disappearance, a key mortality factor. In view of spiders' presumed importance as DFTM predators, Moldenke et al. (1987) provide a key to common spiders on Douglas fir and true fir.

An earlier study by this laboratory (Dahlsten et al. 1977) found spiders abundant in the canopy of white fir, *Abies concolor* (Gordon & Glendinning), in association with the Douglas-fir tussock moth in California. In that study, 23 species of spiders in 10 families were associated with DFTM. A conservative estimate was calculated of at least one free-living spider per four early instar DFTM larvae. These spiders, thought the most likely spider predators of early instar larvae, were 37% of the

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total spiders collected. Spiders were also counted in a study designed to develop a sampling program for DFTM larvae at low population levels (Dahlsten et al. 1985). Spiders were the most common arthropods collected from intensively sampled white fir trees; 52 species from 16 families were recorded.

To assess the possible importance of spiders in the natural enemy complex, this laboratory study tested the feeding capabilities of spiders associated with the DFTM and the white fir sawfly on white fir in central California. Eighteen species of spiders from eight families were tested.

MATERIALS AND METHODS

In July, 1975, the foliage of white firs on three sample plots in El Dorado Co., California (Iron Mountain, Baltic Ridge, and Plummer Ridge) was sampled for larval Douglas-fir tussock moth according to a midcrown sampling procedure described by Mason (1970). These plots were located in a west-slope Sierra mixed conifer forest dominated by white fir in association with several other coniferous species, including ponderosa pine, *Pinus ponderosa* Lawson, and incense cedar, *Calocedrus decurrens* (Torrey) Florin. Dahlsten et al. (1977) sampled tussock moth on these same plots from 1971–1973.

Over a period of 30 days, in three repeat sampling periods, 674 live spiders suitable for the feeding study were collected from the midcrown samples of 240 white firs. The spiders were assigned preliminary identification and placed individually into 20-dram vials stoppered with moist cotton. The vials were transported to the laboratory of the U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station (PSW) in Berkeley, California.

Immediately upon receipt of the live spiders at PSW, a sawfly or DFTM larva was introduced into each vial. The cotton plug was remoistened to prevent desiccation of spider or larva. Late instar (fourth and fifth) larvae of *N. abietis* were obtained from the midcrown field samples, while first through fourth instar DFTM larvae were obtained from laboratory populations at PSW. The larval instar offered each spider was based on the size of the spider. Most spiders collected were immatures, and due to their small size could presumably feed effectively only on first and second instar tussock moth larvae, which range from 2–10 mm in length. Penultimate instar or mature tussock moth larvae were assumed to be too large for capture by most spiders available, except for some larger adult Philodromidae and Thomisidae species. Similarly, the fourth and fifth instar larvae of *N. abietis* were too large for many spider species. In all, 563 DFTM trials and 111 sawfly trials were performed.

Spider behavior was observed for one hour immediately after introduction of the larva, and thereafter for two hours every 24 hours for seven days. Capture and feeding behavior, web and retreat construction, other spider activity, and mortality were noted. Evidence of feeding was either direct observation of capture and feeding on the introduced larva; or desiccated, rolled or otherwise deformed larval wastes in webs or retreats. Enlarged spider abdomens following suspected feeding were corroborating evidence. All spiders were preserved for subsequent identification.

RESULTS AND CONCLUSIONS

All spider species, 18 species in eight families, fed on first, second, and/or third instar DFTM larvae (Table 1). Previous observations indicated that spiders were

most capable of feeding on first and second instar larvae. However, this is not strongly evident in Table 1. Due to the sporadic availability of field collected spiders, total numbers of third instar trials were small and are difficult to compare by spider species with the larger first and second instar trials. Overall, predation rate was about the same on first and second instars ($n = 486$) as on third and fourth instars ($n = 77$); about 35% of spiders fed on each group. Of the four free-living spider species with more than 40 trials, *Xysticus locuples* Keyserling and *Metaphidippus* sp. had lower rates of predation on older instars, but the rates are based on only nine and three late instar larvae respectively. For the two frequently collected web-spinners, *Pityophantes* sp. fed on first and second instars more than on third instars, and Linyphiidae sp. more on first than on second instars. These rates are based on trials with only 15 and four later instar larvae.

In the field free-living spiders may be more important predators than web-spinners for this wingless prey, although both DFTM and sawfly larvae drop from foliage during dispersal or to escape from natural enemies. In this study predation rates on DFTM larvae were similar, 38% and 33% respectively for free living and web spinning spiders. This is not surprising because all prey was placed close to spiders in a confined space.

Seven spider species in four families, of the 16 species in eight families tested, fed on fourth or fifth instar *N. abietis* complex (Table 2). Overall, only 16% of the spiders fed on the larvae, compared to 35% for DFTM. Because conditions for feeding tests with the two prey species differed (both sawfly larvae and the spiders confined with them were larger and older than in the DFTM trials), the difference in feeding rates cannot be attributed to prey species without further testing. Free-living spiders fed on the sawfly larvae in 11% of the trials ($n = 71$), whereas web-spinners fed on 25% of the offered prey ($n = 40$). Again, this difference under artificial conditions does not necessarily reflect predation rates in the field.

Free-living forms such as *Apollophanes margareta* (Lowrie & Gertsch), *Philodromus rufus* Walckenaer, and *P. spectabilis* Keyserling (Philodromidae), *Xysticus locuples* and *Misumenops lepidus* (Thorell) (Thomisidae), and *Metaphidippus* spp. (Salticidae), often immediately attacked larvae and fed through the head capsule or just behind the head on either the dorsal or ventral surface, largely avoiding the dorsal tussocks. The urticating hairs of *O. pseudotsugata* apparently did not deter feeding. One large adult female *X. locuples* attacked and consumed a large (20–25 mm) fourth instar *O. pseudotsugata* larva (Table 1). *Metaphidippus* spp. often captured *O. pseudotsugata* larvae and carried them into web retreats previously constructed in the vial. One female *Philodromus rufus*, having laid eggs in the vial prior to the introduction of prey, immediately took the introduced tussock moth larva and consumed it while remaining in a protective position over the clutch. Jennings & Pase (1975) observed similar behavior of a female oxyopid feeding on *Ips pini* (Say).

Our observations of successful salticid feedings are consistent with Turnbull's (1956) laboratory and field observations with the spruce budworm. He observed that spiders were not repelled by the "violent thrashing and oral exudation of a sticky, brown, evil-smelling liquid" of first through third instar spruce budworm larvae (sawfly larvae also exude a repellent fluid). However, he found that fourth and fifth instar larvae often did repel spiders. Our results with thomisids differ from Turnbull's. In his study, thomisids did not capture spruce budworms in the laboratory or the field.

Table 1. Spider taxa and feeding on *Orgyia pseudotsugata* larvae. Spiders collected from *Abies concolor* on Iron Mountain, Baltic Ridge, and Plummer Ridge, El Dorado County, California, July 1975. M = male. F = female.

	Larval instar	Total trials	Feeding	M	F	I.U. ^a	Non-feeding	Dead	% of sample feeding
Free-living spiders									
Philodromidae									
<i>Apollophanes margareta</i> Lowrie & Gertsch	1st	28	8	0	0	8	13	7	28.6
	2nd	15	10	0	0	10	5	0	66.6
	3rd	16	9	0	0	9	7	0	56.3
	4th	<u>1</u>	<u>1</u>	<u>0</u>	<u>0</u>	<u>1</u>	<u>0</u>	<u>0</u>	<u>100.0</u>
	Total	60	28	0	0	28	25	7	46.7
<i>Philodromus rufus</i> Walckenaer	1st	22	7	0	6	1	13	2	31.8
	2nd	21	8	1	6	1	13	0	38.1
	3rd	<u>13</u>	<u>4</u>	<u>0</u>	<u>3</u>	<u>1</u>	<u>9</u>	<u>0</u>	<u>30.8</u>
	Total	56	19	1	15	3	35	2	33.9
<i>Philodromus spectabilis</i> Keyserling	3rd	3	2	0	1	1	1	0	66.6
<i>Philodromus speciosus</i> Gertsch	2nd	2	2	0	0	2	0	0	100.0
Thomisidae									
<i>Xysticus locuples</i> Keyserling	1st	20	11	0	0	11	9	0	55.0
	2nd	14	3	0	0	3	11	0	21.4
	3rd	8	1	0	0	1	7	0	12.5
	4th	<u>1</u>	<u>1</u>	<u>0</u>	<u>1</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>100.0</u>
	Total	43	16	0	1	15	27	0	37.2
<i>Misumenops lepidus</i> (Thorell)	1st	2	2	1	0	1	0	0	100.0
	3rd	<u>1</u>	<u>1</u>	<u>0</u>	<u>1</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>100.0</u>
	Total	3	3	1	1	1	0	0	100.0
Salticidae									
<i>Metaphidippus</i> sp.	1st	78	25	1	0	24	37	16	32.0
	2nd	17	5	0	1	4	12	0	29.4
	3rd	<u>3</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>3</u>	<u>0</u>	<u>00.0</u>
	Total	98	30	1	1	28	52	16	30.6
<i>Metaphidippus harfordi</i> (Peckham)	1st	5	2	0	0	2	3	0	40.0
	2nd	2	2	0	1	1	0	0	100.0
	3rd	<u>3</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>3</u>	<u>0</u>	<u>00.0</u>
	Total	10	4	0	1	3	6	0	40.0
Anyphaenidae									
<i>Anyphaena pacifica</i> (Banks)	1st	7	4	0	0	4	3	0	57.1
	3rd	<u>2</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>2</u>	<u>0</u>	<u>00.0</u>
	Total	9	4	0	0	4	5	0	44.4
Web-building spiders									
Linyphiidae									
<i>Pityohyphantes</i> sp.	1st	47	19	0	0	19	28	0	40.4
	2nd	3	1	0	0	1	2	0	33.3
	3rd	<u>15</u>	<u>1</u>	<u>1</u>	<u>0</u>	<u>0</u>	<u>14</u>	<u>0</u>	<u>6.6</u>
	Total	65	21	1	0	20	44	0	32.3

Table 1. Continued.

	Larval instar	Total trials	Feeding	M	F	I.U. ^a	Non-feeding	Dead	% of sample feeding
Linyphiidae sp.	1st	109	31	14	0	17	77	1	28.4
	2nd	45	5	1	0	4	38	2	11.1
	3rd	4	4	0	0	4	0	0	100.0
	Total	158	40	15	0	25	115	3	25.3
<i>Prolinyphia</i> sp.	3rd	3	3	1	1	1	0	0	100.0
Araneidae									
<i>Araniella displicata</i> (Hentz)	1st	14	4	0	0	4	10	0	28.6
	2nd	3	0	0	0	0	3	0	00.0
	3rd	2	0	0	0	0	2	0	00.0
	Total	19	4	0	0	4	15	0	21.0
<i>Araneus</i> sp. 1	1st	10	6	0	0	6	3	1	60.0
	2nd	2	2	0	0	2	0	0	100.0
	Total	12	8	0	0	8	3	1	66.6
<i>Araneus</i> sp. 2	1st	5	4	0	0	4	0	0	80.0
Dictynidae									
Dictynidae sp. 1	1st	5	5	0	0	5	0	0	100.0
Theridiidae									
<i>Theridion neomexicanum</i> Banks	1st	1	1	1	0	0	0	0	100.0
	2nd	2	2	0	2	0	0	0	100.0
	Total	3	3	1	2	0	0	0	100.0
Agelenidae									
Agelenidae sp. 1	1st	3	2	0	0	2	0	1	66.6
	2nd	4	1	0	0	1	3	0	25.0
	3rd	2	0	0	0	0	2	0	00.0
	Total	9	3	0	0	3	5	1	33.3
Total sample size		563	199						34.8

^a Immature, sex undetermined.

Web-building forms such as *Araniella displicata* (Hentz), *Araneus* spp., Agelenidae, *Anyphaena pacifica* (Banks), and Linyphiidae spun webs in the vials, and spun additional webbing around entangled larvae before consuming them. Web-building spiders most often fed upon captured larvae through the head capsule or ventrally, midway along the length of the larva. These laboratory observations are again consistent with Turnbull's (1956) field observations of spiders and the spruce budworm. Many of the genera and species used in this study were also used in Turnbull's study.

The results of these feeding trials may have been complicated by factors such as differing feeding by spiders in the field prior to collection, differences in size and maturity of the spiders fed different larval instars (e.g., adult males may not feed), onset of molting, and small size of the feeding environment (in a confined space, spiders may accept food they would not eat in the field). However, the results do indicate the ability of these species to feed on the defoliators. In a

Table 2. Spider taxa and feeding on *Neodiprion abietis* complex larvae. Spiders collected from *Abies concolor* on Iron Mountain, Baltic Ridge, and Plummer Ridge, El Dorado County, California, July 1975. M = male. F = female.

	Larval instar	Total trials	Feeding	M	F	I.U. ^a	Non-feeding	Dead	% of sample feeding
Free-living spiders									
Philodromidae									
<i>Apollophanes margareta</i>	4/5	24	3	0	0	3	20	1	12.5
<i>Philodromus rufus</i>	4/5	19	1	0	1	0	15	3	5.3
Thomisidae									
<i>Xysticus locuples</i>	4/5	11	3	0	1	2	8	0	27.3
<i>Misumenops lepidus</i>	4/5	2	0	0	0	0	1	1	00.0
Salticidae									
<i>Metaphidippus</i> sp. 1	4/5	10	1	0	0	1	8	1	10.0
Anyphaenidae									
<i>Anyphaena pacifica</i>	4/5	5	0	0	0	0	4	1	00.0
Web-building spiders									
Linyphiidae									
<i>Pityohyphantes</i> sp.	4/5	10	0	0	0	0	7	3	00.0
<i>Prolinyphia</i> sp.	4/5	3	0	0	0	0	2	1	00.0
Linyphiidae sp. 1	4/5	2	0	0	0	0	2	0	00.0
Araneidae									
<i>Araniella displicata</i>	4/5	5	2	0	2	0	3	0	40.0
<i>Araneus</i> sp. 1	4/5	2	1	0	0	1	1	0	50.0
<i>Araneus</i> sp. 2	4/5	4	0	0	0	0	4	0	00.0
Dictynidae									
Dictynidae sp. 1	4/5	2	0	0	0	0	1	1	00.0
Theridiidae									
<i>Theridion neomexicanum</i>	4/5	9	7	0	4	3	1	1	77.8
<i>Dipoena</i> sp.	4/5	2	0	0	0	0	1	1	00.0
Agelenidae									
Agelenidae sp. 1	4/5	<u>1</u>	<u>0</u>	0	0	0	1	0	<u>00.0</u>
Total sample size		111	18						16.2

^a Immature, sex undetermined.

limited 1976 field trial, predation also occurred when free-living spiders were caged with DFTM larvae on white fir branches (Dahlsten et al. 1978).

This laboratory study is a preliminary step in determining the role of spiders in the DFTM and white fir sawfly complex on white fir. Further research should examine predation in the field, not only on larvae but also on tussock moth egg masses just prior to eclosion. Such studies should match spiders of different age classes with defoliator instars that they actually encounter in the field. Free-living forms such as Thomisidae and Salticidae species are especially amenable to field studies on caged foliage. The effect of spiders on other natural enemies of DFTM and sawflies should also be studied, to help determine the net effect of spider predation on the defoliators. Finally, although spiders are difficult and costly to

raise in mass because of their cannibalistic nature, efforts should be made in order to evaluate experimental augmentation of forest spider populations.

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